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Aboveground Carbon Stock and Soil Nutrient Status of *Acacia mangium* under Silvipastoral System

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Abstract

Acacia mangium is highly valued tree species for its multiple uses and well suited to silvipastoral system under Agroforestry. A trial was conducted at Assam Agricultural University, Horticultural Research Station, Kahikuchi, Guwahati, Assam during 2017 to 2022. The experiment was laid in Randomaized Block Design where fodder hybrid napier was grown as intercrop with 13 years old tree species *Acacia mangium* planted at different spacing of 5 m x 6 m, 5 m x 5 m and 5 m x 4 m.The growth parameters of tree, tree height, diameter at breast height, canopy diameter, timber volume, above ground carbon stock were observed during the years. The maximum plant height (16.30 m), dbh (35.97 cm), timber volume (411.98 m^3ha^{-1}), tree biomass (512.55 Mg ha^{-1}) and above ground carbon stock (256.28 Mg ha^{-1}) were recorded in intercrop plot where tree spaced at 5 m x 4 m with fodder. Increase of organic matter in soil recorded maximum (37.76 %) in intercrop plot where tree spaced at 5 m x 4 m from initial. The highest increase of available N (29.10 %), available P_2O_5 (30.35 %)and available K_2O (14.71%) were observed in soil under tree + intercrop at spacing of 5 m x 4 m over the initial year of plantation. In silvipastoral system of agroforestry *Acacia mangium* would be a prominent species with fodder grass in climate change scenario.

***Key words :** Agroforestry, sivipastoral, timber volume, carbon stock,organic matter.*

Introduction

Acacia mangium is a very fast growing evergreen tree species growing up to 30 m height and 0.5 m diameter. It is typically found in the tropical, humid zone characterized by a short dry season and a mean annual rainfall between 150-3000 mm; it can tolerate moisture stress, temperature requirement ranges from 31-37^{0}C during summer and a minimum of 12-25^0 C in winter. The growth seems to be slow down with decreasing rainfall and temperature. *Acacia mangium* can tolerate low fertility soils with impeded drainage, but prefers fertile soils with good drainage. *Acacia mangium* is used to make excellent particle board and is suitable for plywood, paper pulp, fence posts, firewood and charcoal. It is important source of wattle timber; the wood is used for construction, boat building, furniture and cabinet making, and veneer. It makes attractive cabinets, mouldings, floors, and door and window components. Young shoots and leaves are browsed by buffalo and cattle. For production of honey *Acacia mangium* is a suitable crop. *Acacia mangium* is very fast growing and possesses the beneficial property of trapping atmospheric nitrogen; thereby increases soil organic matter and nutrients. It is the most suitable tree species for soil improvement in degraded and marshy land. Clean environment is obtained through the fixation of 170.9 Mg ha^{-1} of CO_2 in the form of wood in 16 year *plantation* of *Acacia mangium* in Assam.

Agroforestry practices help mitigate climate change and support the livelihoods of smallholder farmers (1, 2). The ability of agroforestry to capture carbon varies depending on climatic conditions, the age and management of trees in the landscape, and the method used to measure biomass (3). The species of trees have been found to have the greatest influence on carbon storage, determining the maximum amount of carbon that can be stored under favorable conditions (4). Silvopastoral systems are a type of agroforestry where trees and pastures coexist and are utilized for animal production. The goal of these systems is to enhance productivity in a sustainable manner, while also achieving other benefits (5).The inclusion of legumes that fix nitrogen to the soil and trees with taproots that use the deep ground layers and recycle nutrients in silvopastoral systems helps increase the physical protection of the soil and contributes to the recovery of fertility, thereby serving as an alternative to reverse the processes of degradation in the grasslands (6).

As the adverse effects of conventional agricultural practices on ecosystems become more pronounced, there is increasing discourse around transitioning to more sustainable production systems. Silvopasture, which involves integrating trees, forage, and livestock, has been suggested as a potential approach to bolster

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agroecological and community resiliency in response to climate change (7). The silvopastoral systems are very important in the carbon sequestration in the soils and in the woody biomass (8). Accoring to (6), these systems provide two main benefits to preserve the carbon: they contribute to the direct storage of C, at short and middle term (decades up to centuries) in the trees and the soil, and reduce indirectly the release of greenhouse effect gases, caused by the deforestation and the migratory agriculture. The amount of C fixed in these systems can be affected by the type of grass and tree species, the density and the space distribution of the woody trees and by the shade tolerance of the herbaceous species (9). Agroforestry can contribute significantly to carbon sequestration in agricultural lands, as carbon accumulates both in tree biomass and the soil (10).

Materials and Methods

The experiment was conducted at Assam Agricultural University, Horticultural Research Station, Kahikuchi, Guwahati, Assam, India situated at latitude 26°3'N, longitude 91°7'E and 64.0 m above mean sea level under Indian Council of Agricultural Research (ICAR)-All India Coordinated Research Project (AICRP) on Agroforestry. It receives an average annual rainfall ranging from 1800 -2000 mm. The pH of topsoil varied from 4.7 to 5.4.The soil of experimental site was fine loamy mixed hyperthermic Dystric Eutrudept soil. One year old seedlings of *Acacia mangium* were planted on 25.06.2004 at the spacing of 5 m x 4 m, 5 m x 5 m and 5 m x 6 m. Inter crop sequence sesamum niger / toria was done upto 2007-08 after which field crops could not be grown due to tree canopy; however, fodder crop Hybrid napier was grown during 2017-18 onwards. Two third of the 9-year-old trees were thinned out for promoting the timber growth of the superior trees. The branches were regularly pruned during winter season during the period of experimentation. The data on tree height, diameter at breast height (dbh), timber volume and biomass were recorded regularly in November every year. The soil samples were collected randomly by using auger at regular intervals for estimation of available nitrogen, phosphorus, potassium and organic carbon.

The tree height and dbh of these trees including multistemmed were measured according to (11).

Timber Volume : Timber volume for an individual tree was calculated where the square of girth at breast height (gbh) was divided by 12.56 and multiplied by the tree height and the factor of 0.65 prescribed for Acacia type tree.

Timber volume (m^3 per tree) = $(gbh)^2/12.56 \times H \times F$

Where,

gbh = Girth at breast height in meter

H = Tree height in meter

F = Factor (0.65) for *Acacia* type tree

Timber volume per ha = Timber volume per tree x no.of trees per ha

Aboveground Biomass (AGB) : The aboveground biomass (AGB)of the inventory trees was estimated using Allometric equations developed for tropical moist forest (12).

AGB (Y) = Exp {-2.134 + 2.530 x LN (dbh)}

Where,

Y= Biomass per tree in kg

Exp= Exponential function

D= dbh in cm

LN= Natural logarithm

AGB per ha=Y×No. of tree per ha/1000=Mg ha^{-1}

Soil Sampling and Analysis : From the experimental plot, we selected five locations at random, and from each location, six composite surface soil samples (0-15cm) were collected randomly in 2004 and periodically from 2017 to 2022 before the onset of the monsoon. The collected samples were dried under shade and soil parameters were measured using (13) methods. The alkaline potassium permanganate method was used for the determination of available Nitrogen using Kel plus. Available phosphorus and potassium in soil was determined colorimetrically by (14) and Ammonium Acetate Extraction method (13) using a flame photometer, respectively.

Results and Discussion

From the four years experiment it was found that the maximum plant height (16.30 m) recorded in 5m x 5m spacing but the height which were non significant. The maximum dbh (35.92 cm) was recorded in 5 m x 4 m spacing and it was significantly higher than all other treatments in 2021-22. There was gradual increase in plant height and dbh from the year 2017 onwards (Table-1). Maximum timber volume (411.98 m^3 ha^{-1}), tree biomass (512.55 Mg ha^{-1}) and aboveground carbon (256.28 Mg ha^{-1}) were recorded maximum in 5 m x 4 m spacing in *Acacia mangium* tree with fodder Hybrid napier in 2021-22 and it was observed that there was increase of all values from 2017 to 2021 in all the treatments. (Table-2). The findings were in conformity with that of (15) who also reported an increase in timber volume at the rate of 60.7 m^3 per year in *A. mangium*. The slow increase of biomass during the period but later on it leaded a stable

Table-1 : Plant height and dbh of *Acacia mangium* in silvipastoral system (2017-2021).

Treatment	Height (m)					dbh (cm)				
	2017-18	2018-19	2019-20	2020-21	2021-22	2017-18	2018-19	2019-20	2020-21	2021-22
Sole tree at 5m x 4m	13.23	13.23	13.85	14.12	14.19	28.89	29.76	30.78	30.98	31.23
Tree at 5m x 4m + Fodder	12.78	15.37	15.98	16.23	16.30	27.02	32.87	35.32	35.79	35.97
Sole tree at 5m x 5m	13.22	14.37	14.88	15.12	15.18	25.57	26.33	27.26	27.97	28.21
Tree at 5m x 5m+ Fodder	13.67	14.48	15.01	15.45	15.51	24.60	28.32	32.04	32.47	32.60
Sole tree at 5m x 6m	11.44	13.67	14.04	14.39	14.45	29.05	29.92	30.89	31.24	31.54
Tree at 5m x 6m+ Fodder	13.81	14.25	14.62	14.83	14.88	26.66	27.46	28.36	30.87	31.06
S.Ed. (+)	1.42	0.90	1.18	1.20	1.25	2.80	2.89	0.87	0.97	1.02
CD (5%)	NS	NS	NS	NS	NS	NS	NS	1.90	2.11	2.22

Table 2 : Timber volume and tree biomass of *Acacia mangium* in silvipastoral system (2017-2021).

Treatment	Timber volume (m^3 ha^{-1})					Tree biomass (Mg ha^{-1})					Above ground carbon stock (Mgha^{-1})
	2017-18	2018-19	2019-20	2020-21	2021-22	2017-18	2018-19	2019-20	2020-21	2021-22	2021-22
Sole tree at 5m x 4m	187.5	207.1	221.53	289.33	315.33	293.5	334.5	380.67	349.91	357.65	178.82
Tree at 5m x 4m + Fodder	138.3	297.0	405.60	409.61	411.98	199.0	407.0	507.73	504.84	512.55	256.28
Sole tree at 5m x 5m	123.6	140.4	181.89	329.16	335.22	184.0	201.7	203.21	216.23	221.21	110.60
Tree at 5m x 5m + Fodder	166.1	180.3	258.2	311.03	320.34	238.0	276.2	306.24	314.56	318.95	159.47
-90Sole tree at 5m x 6m	90.4	98.3	167.43	377.22	389.68	143.6	160.2	231.97	238.18	244.22	122.11
Tree at 5m x 6m+ Fodder	123.2	133.4	183.37	281.33	295.56	159.6	178.5	186.93	231.27	234.93	117.46
S.Ed. (+)	36.09	42.61	52.64	53.65	54.08	64.36	4.95	29.27	30.22	32.11	16.78
CD (5%)	78.64	92.89	114.76	116.96	117.89	140.24	10.53	63.81	65.88	68.00	36.58

Table-3 : pH (1:2.5 soil: water) status of soil under *Acacia mangium* in silvipastoral system (2017-2021).

Treatment	2004-05	2017-18	2018-19	2019-20	2020-21	2021-22
Sole tree at 5m x 4m	4.92	5.33	5.38	5.40	5.42	5.42
Tree at 5m x 4m + Fodder	4.92	5.28	5.32	5.32	5.35	5.36
Sole tree at 5m x 5m	4.87	5.35	5.37	5.36	5.38	5.38
Tree at 5m x 5m + Fodder	4.87	5.24	5.32	5.32	5.33	5.35
Sole tree at 5m x 6m	4.75	5.29	5.30	5.31	5.32	5.33
Tree at 5m x 6m+ Fodder	4.75	5.26	5.27	5.27	5.29	5.30
S.Ed. (+)	0.10	0.02	0.06	.026	0.034	0.034
CD (5%)	NS	0.04	NS	0.057	0.075	0.075

biomass. This confirmed the findings of (16), that the biomass including AGB of most *A. mangium* tree components, increased with an increase in stand age. According to (17), the tree with the highest dbh recorded higher carbon stock. The aboveground CO_2 sequestration also showed an increasing trend. (17, 18) stated that the broader the leaves, the thicker the crown cover, and consequently the denser the cluster, the more the CO_2 sequestration potential of the trees. In silvopastoral systems, the total biomass production is usually higher than in monocultures. However, the interactions between the components of these systems during the exploitation time can determine the productive capacity (19). It is logical to state the hypothesis that the silvopastoral systems, by combining improved grasses and strata of deeper roots, may have higher carbon capture rates (20).

The maximum fodder yield of Hybrid napier (50.65 t ha^{-1}) was obtained in sole fodder followed by tree spaced at 5 m x 6 m (46.29 t/ha), 5 m x 5 m (40.56 t ha^{-1}) and 5 m x 4 m (39.24 t ha^{-1}) in 2021 respectively.

The pH of the soil was increased from the initial 4.92 to 5.42 in sole tree at 5m x 4m spacing (Table-3). The increase of OM status in soil was the maximum (37.76 %) in intercrop plot where tree spaced at 5m x 4m after 17 years of plantation with hybrid napier. Higher rate of

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